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INTRODUCED AMPHIBIANS AND REPTILES IN THE CUBAN ARCHIPELAGO

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Abstract.—**The number of introductions and resulting established populations of amphibians and reptiles in Caribbean islands is alarming. Through an extensive review of information on Cuban herpetofauna, including protected area management plans, we present the first comprehensive inventory of introduced amphibians and reptiles in the Cuban archipelago. We classify species as Invasive, Established Non-invasive, Not Established, and Transported. We document the arrival of 26 species, five amphibians and 21 reptiles, in more than 35 different introduction events. Of the 26 species, we identify 11 species (42.3%), one amphibian and 10 reptiles, as established, with nine of them being invasive: *Lithobates catesbeianus*, *Caiman crocodilus*, *Hemidactylus mabouia*, *H. angulatus*, *H. frenatus*, *Gonatodes albogularis*, *Sphaerodactylus argus*, *Gymnophthalmus underwoodi*, and *Indotyphlops braminus*. We present the introduced range of each of the 26 species in the Cuban archipelago as well as the other Caribbean islands and document historical records, the population sources, dispersal pathways, introduction events, current status of distribution, and impacts. We compare the situation of introduced herpetofauna in Cuba with that in other Caribbean islands. We also document impacts, areas of missing information, and possible directions for future research. The paper contributes a systematic review as well as new knowledge for national and international agencies and databases. This information is critical for use in conservation, management, and eradication. Additionally, it alerts management authorities as to specific pathways of introduction for proactive action, which may be used to avoid potential introductions.**

Key Words.—Caribbean; exotic species; impacts; invasive species; island; pathways; protected areas

INTRODUCTION

Biological invasions have claimed the urgent attention of the international scientific community for their negative impacts on ecology, economies, and public health (Lever 1994; Simberloff and Rejmánek 2011). Preliminary annual estimates of the total costs of invasive species are $12.5–20 billion EUR in Europe (Kettunen et al. 2008) and around $33.5 billion US in Southeast Asia (Nghiem et al. 2013). Additionally, damage from invasive species worldwide is estimated at more than $1.4 trillion US or 5% of the global economy (Pimentel et al. 2001). These alien species (*sensu* Kraus) are threatening native biodiversity and are expanding by means of deliberate and accidental introductions as a result of increasing commerce and communication routes, as well as through irresponsible human actions (Kraus 2003, 2007, 2011). The introduction of invasive species is the major cause of biodiversity loss after the destruction and modification of habitats by human activities (Wilcove et al. 1998; McGeoch et al. 2010; Simberloff and Rejmánek 2011). Invasive species reduce the abundance and richness of native biota mainly through predation, competition, alteration of habitats, serving as disease vectors, and decreasing genetic diversity through hybridization (Lever 1994; Kraus 2009). Clavero and García-Berthou (2005) reported the cause of extinction for 170 animal species from the IUCN Red List database, of which 91 (54%) include the effects of invasive species and 34 (20%) had invasive species as the only cause of extinction. At least 678 amphibian and reptile species are documented to have been introduced outside their native ranges by humans, with at least 322 species established, resulting in more than 1,060 populations of introduced amphibians and reptiles in the world (Kraus 2009, 2011).

Impacts from invasive species are particularly large on small islands, given their recognized fragility and vulnerability (Courchamp et al. 2003; Kairo et al. 2003; Sax and Gaines 2008; Drake and Hunt 2009; McGeoch et al. 2010). The Caribbean islands are one of the global biodiversity hot spots for conservation because of their extraordinary species richness and high levels of endemism (Myers et al. 2000; Smith et al. 2005; Wege et al. 2010). These islands have a long biotic history of colonization, radiation, speciation, and extinction

(Woods and Sergile 2001) and have been recognized as a natural laboratory for the study of biogeography and evolution (Ricklefs and Bermingham 2007). Worldwide, 71.6% of all mammalian extinctions have taken place on islands, while 37.5% of all modern-era extinctions occurred in the Caribbean islands (MacPhee and Marx 1997; MacPhee and Flemming 1999). Additionally, Henderson (1992) re-interpreted the data of Honegger (1981), who reviewed the number of amphibians and reptiles that presumably have become extinct since 1600, and concluded that 50% of the world's extinctions were in the Caribbean islands. Furthermore, a minimum of 7–12 extinctions and 12–13 extirpations of amphibians and reptiles have occurred in the Caribbean islands in the past 155 y and some species have become extinct based on introduced predator effects (Henderson 1992). This insular region has been the scene of multiple introduction events, with some species becoming invasive, having several deleterious effects on native biota (Powell et al. 2011, 2013; Hedges and Caitlin 2012). Invasive species are considered the principal threat for reptile conservation in the Caribbean islands (Böhm et al. 2013).

The Cuban archipelago represents an important example of radiation and diversification for vertebrates (Fontenla 2007; Ricklefs and Bermingham 2007). An archipelagic state of over 4,000 islands and cays, Cuba represents more than half the islands in the Caribbean Sea, and the main island, with a coastline of over 5,700 km, is the largest island in the Caribbean Sea (Servicio Hidrográfico y Geodésico de la República de Cuba 2003). The Red Book of Cuban Vertebrates (González Alonso et al. 2012) lists 655 species, including more than 250 endemic species, of which 167 are threatened. Endemism rates in Cuba are extremely high for amphibian (95.4%, Rivalta et al. 2014) and reptile (80%, Rodríguez Schettino et al. 2013) species.

Introduced mammals and invasive plants have received the primary attention in Cuba (Borroto-Páez 2009, 2011; Borroto-Páez and Woods 2012; Oviedo et al. 2012 a, b). Although the country is working to achieve a national strategy to prevent, control, and manage invasive species, the inventory of invasive vertebrates and their possible impacts is still insufficient (Escobar 1995; Vales et al. 1998; Kairo et al. 2003; Powell et al. 2011). Moreover, regional databases (CIASNET. 2015. Caribbean Invasive Alien Species Network. Available from http://www.ciasnet.org/; Hedges, S. B. 2015. Cariherp. West Indies Amphibians and Reptiles. Pennsylvania University, University Park, Pennsylvania, USA. Available from http://www.caribherp.org [Accessed 17 March 2015]) and some important international databases (Centre for Agriculture and Biosciences International. 2015. Invasive Species Compendium. CAB International, Wallingford, UK. Available from http://www.cabi.org/isc [Accessed 17 March 2015]; Invasive Species Specialists Group (IUCN). 2015. Global Invasive Species Database. Available from http://www.issg.org/database/welcome/ [Accessed 17 March 2015]; Island Conservation. 2015. Threatened Island Biodiversity Database. Available from http://tib.islandconservation.org/ [Accessed 17 March 2015]; GIASI Partnership. 2015. Global Invasive Alien Species Information Partnership. Available from http://giasipartnership.myspecies.info/en [Accessed 17 March 2015]) do not contain updated information on the status of invasive vertebrate species in Cuba. Herein we present a comprehensive review of introduced amphibians and reptiles of the Cuban archipelago as a start towards rectifying these limitations.

MATERIALS AND METHODS

We conducted an extensive bibliographic review of lists, catalogs, and reports, including gray literature, related to the introduced herpetofauna of Cuban and Caribbean islands. We also reviewed 86 management plans of Cuban protected areas with legal administration (Appendix 1), available as unpublished manuscripts at the National Center for Protected Areas (CNAP, Spanish acronym). Other sources of information are recent and ancient books and papers about Cuban nature, agriculture, veterinary science, conservation, and history. The historical records of many introduced species are uncertain, but Cuban history texts are useful to fix periods of possible introductions linked to historic processes, such as colonization, slavery, republic, and revolutionary stages. We also included information supplied by other specialists including our personal knowledge of Cuban biota and introduced species. Our inventory includes information on amphibians and reptiles that arrived in Cuba with documented evidence and verifiable identification. The first citation of the species in lists, catalogs, or any source and its posterior treatment in successive papers allowed us to establish the more probable times of arrivals.

We present information on non-native amphibian and reptile species transferred to Cuba via human means, and to distinguish the fate of these species after arrival in Cuba, by presenting categories that reflect their survival, establishment, spread, effects and/or impacts. We followed Duncan et al. (2003) regarding the biological concept of invasion. This definition explicitly excludes any connotation of impact, and is based exclusively on ecological and biogeographical criteria. We use the terminology of Duncan et al. (2003) to refer to the species based on their stage in the invasion process (Invasive and Transported terms), and provide terms (Not Established and Established Non-invasive) for two categories listed in the Duncan et al. (2003) conceptual framework but not defined explicitly (see Fig. 1 in Duncan et al. 2003). In doing so, we define four

categories of introduced species for Cuba consistent with the presence of the species in Cuba: (1) Invasive: species transferred from its native geographic range to Cuba, with evidence of release or escape into the wild or human environments. These species have successfully colonized and currently exist in the wild or around human settlements and have increased in abundance and are spreading beyond the release point. These species could be a threat for ecosystems and biodiversity and it could produce ecological or economic impacts; (2) Established Non-invasive: species transferred from its native geographic range to Cuba with evidence of release or escape into the wild or human environments that were successfully colonized during a period of time, but apparently failed. There is no existing evidence of their presence in the wild, and they currently only live associated with humans as pets without demonstrable evidence of impact in nature or the economy. These species were present in the wild in the past, but their current situations have not been adequately evaluated and recent herpetological inventories do not detect them in natural conditions. Their frequent presence as pets, and the continued illegal introductions of new propagules represent a threat; (3) Not Established: species transferred from its native geographic range to Cuba, with evidence of release or escape into the wild or human environments that failed in colonizing with no further trace of their presence currently in Cuba in the wild or even as pets. There is no existing possibility of new propagules from Cuba; (4) Transported: species transferred from its native geographic range, without evidence of release or escape into the wild or human environments. In this category, we include pets or species with economic importance, but not animals imported for zoos and laboratory research (e.g., *Geochelone* spp., *Centrochelys* spp., *Python molurus*, and *Xenopus laevis*).

We included the following information for each species when available: (1) Scientific name and English and Cuban common names when they exist**;** (2) Introduced range in the Caribbean islands by references, not including Cuba; (3) Introduction date and place in Cuba approximated as accurately as possible; (4) Population source as origin of the propagules, specifying country or region; (5) Pathways as means and reasons of introduction; (6) Introduction events and current status referred how the introduction occurred, information on abundance, chronology of published records, and current distribution in Cuba. Data sources include the management plans of Cuban Protected Areas (Appendix 1 lists those with invasive herps) and herpetological collections, principally the Institute of Ecology and Systematics, Havana, Cuba (CZACC), and institutions from the USA sourced from VertNet (VertNet. 2015. Available from http://www.vertnet.org/ [Accessed 17 March 2015]). We also used records from the National Museum of Natural History of Cuba (MNHNCu) and the Eastern Center for Ecosystems and Biodiversity (BSC.H), Santiago de Cuba (vouchers of the most restricted species). These are included as Appendix 2; (7) Impacts referred to damage or negative effect of the introduction (potential or proven impacts) on biodiversity, agriculture, and society. We also classify the level of impact for each species following the categories of Blackburn et al. (2014), an unified classification of alien species based on the magnitude of their environmental impacts, that will permit to compare with other countries and regions; and (8) Comments with information on average or maximum size (SVL, snout-vent length or CL, carapace length) and weight. We present original sources for citations, otherwise information is based on Henderson and Powell (2009), which gives data about body size (SVL), natural history and treatment of the species (native or introduced) in bibliographic sources. Other relevant information about taxonomic status and native distribution range were obtained from AmphibiaWeb (http://amphibiaweb.org/ species) and Reptile Database (http://www.reptile-database.org/), both accessed 17 March 2015.

RESULTS

***Lithobates catesbeianus*, American Bullfrog, Rana Toro (Fig. 1A). Invasive.**

Introduced to Hispaniola, Jamaica, and Puerto Rico (Powell et al. 2011). This species was introduced for the first time by Colonel Charles Hernández in 1916 and 1917 (Gómez de la Maza 1959; MINAGRI 1960). It is probable that other introductions occurred in 1927 (Luis Moreno, pers. comm.) and 1946 (MINAGRI 1960). It came from the United States. This species has been used for aquaculture and food, as well as for exploitation and exportation of frog haunch and skin.

The first introduction was for aquaculture sites in the Wajay area of Havana province, but some animals escaped to neighboring water bodies. Additionally, some animals and eggs were released in rivers, small streams, and lagoons in Pinar del Río, Matanzas, Villa Clara, Camagüey, Oriente and Isla de Pinos (MINAGRI 1960). It is widely distributed now throughout the main island of Cuba and the Isla de la Juventud (Jaume 1966; Schwartz and Henderson 1991; Escobar 1995) and some cays (Díaz and Cádiz 2008), although the cays are not identified (Fig. 2). Luis Díaz (pers. comm.) stated that he has observed *Lithobates catesbeianus* in oxidation ponds on Romano and Coco cays, Sabana-Camaguey Archipelago. The species can also be abundant in rice fields and dams. Moreover it is reported in Leonero Dam in Granma province (Montañez et al. 1985; Sampedro et al. 1985), Guanahacabibes (Novo et al. 1987), and Alonso de Rojas in Pinar del Río province (Sampedro et al. 1985). In the last 10 y, densities have

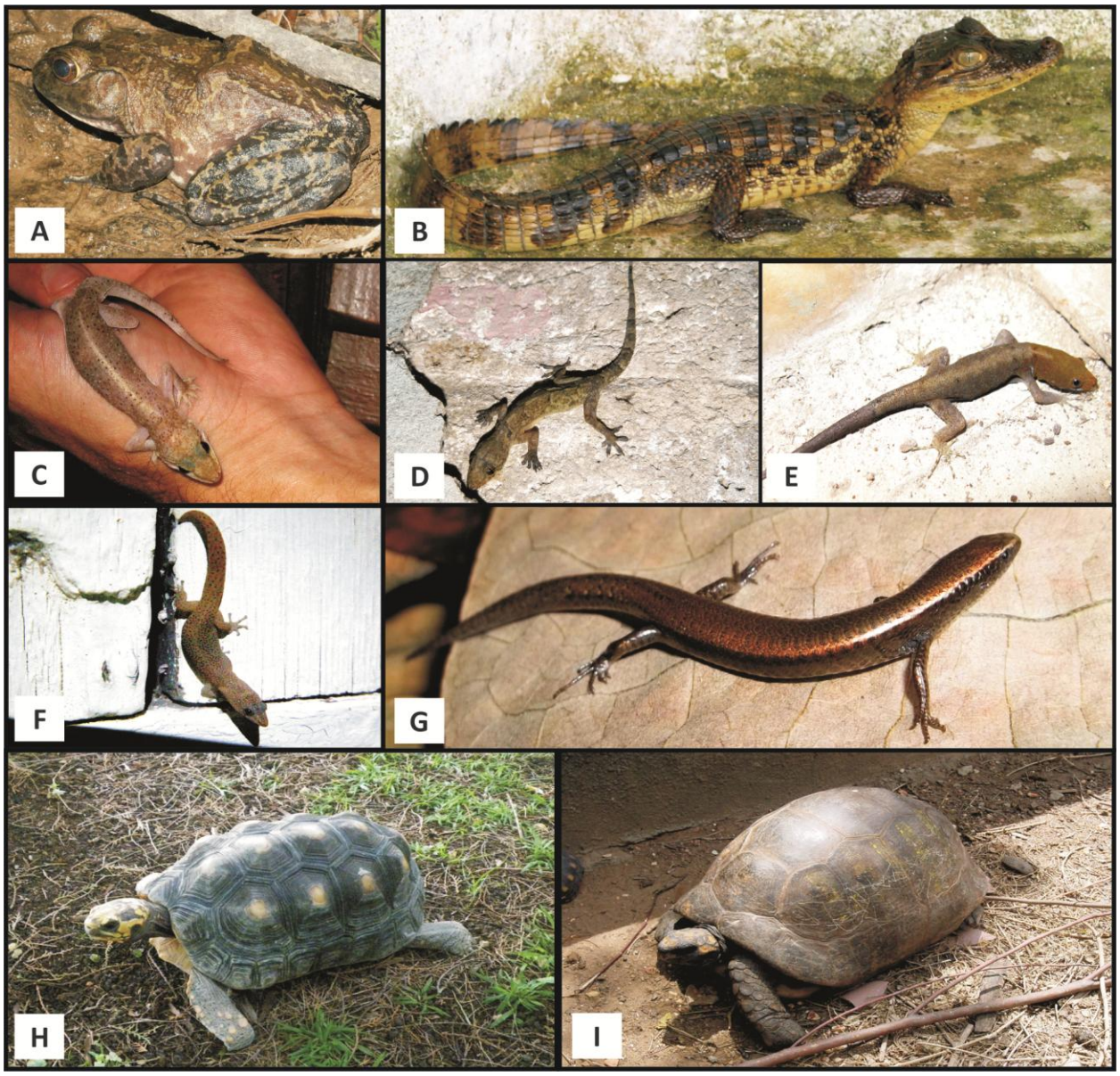

FIGURE 1. Some introduced and invasive amphibians and reptiles in Cuba. (A) American Bullfrog (*Lithobates catesbeianus*), (*B*) Spectacled Caiman (*Caiman crocodilus*), (C) *Hemidactylus angulatus*, (D) Wood Slave (*Hemidactylus mabouia*),(E) Yellow-Headed Gecko (*Gonatodes albogularis fuscus*), (F) Ocellated Gecko (*Sphaerodactylus argus*), (G) Underwood's Spectacled Tegu (*Gymnophthalmus underwoodi*), (H) Red-Footed Tortoise (*Chelonoidis carbonarius*), and (I) Yellow-Footed Tortoise (*Chelonoidis denticulatus*).

declined locally, possibly due to the presence in almost all Cuban water reservoirs (lakes, fishponds, streams, and deep and shallow water natural ponds) of invasive catfish *Clarias* sp., which are predators with a wide prey spectrum (Pérez-Osoria and Figueredo 2013; Ponce de Leon et al. 2013). Invasive mammals, such as cats, mongoose, and dogs, could be potential predators as well. There are 33 specimens in CZACC, collected from six provinces, including Isla de la Juventud. The species is reported in 31 protected areas (Appendix 1). There are additionally 26 specimens deposited in three US collections: USNM (22), FLMNH (3), and AMNH (1); all from western and central Cuba.

We classify their impact as Major (MR). *Lithobates catesbeianus* adults predate many different native vertebrates and invertebrates; stomach content analysis of wild adults in Cuba list: insects (Coleoptera and Orthoptera principally, but also eight other insect orders), crustaceans, mollusks, spiders, diplopods, fishes, other frogs, small turtles, birds, small mammals, and plant material (Sampedro et al. 1985, 2003; Montañez et al. 1996). Predation of bats by *Lithobates catesbeianus* has been reported (Vogel 1965).

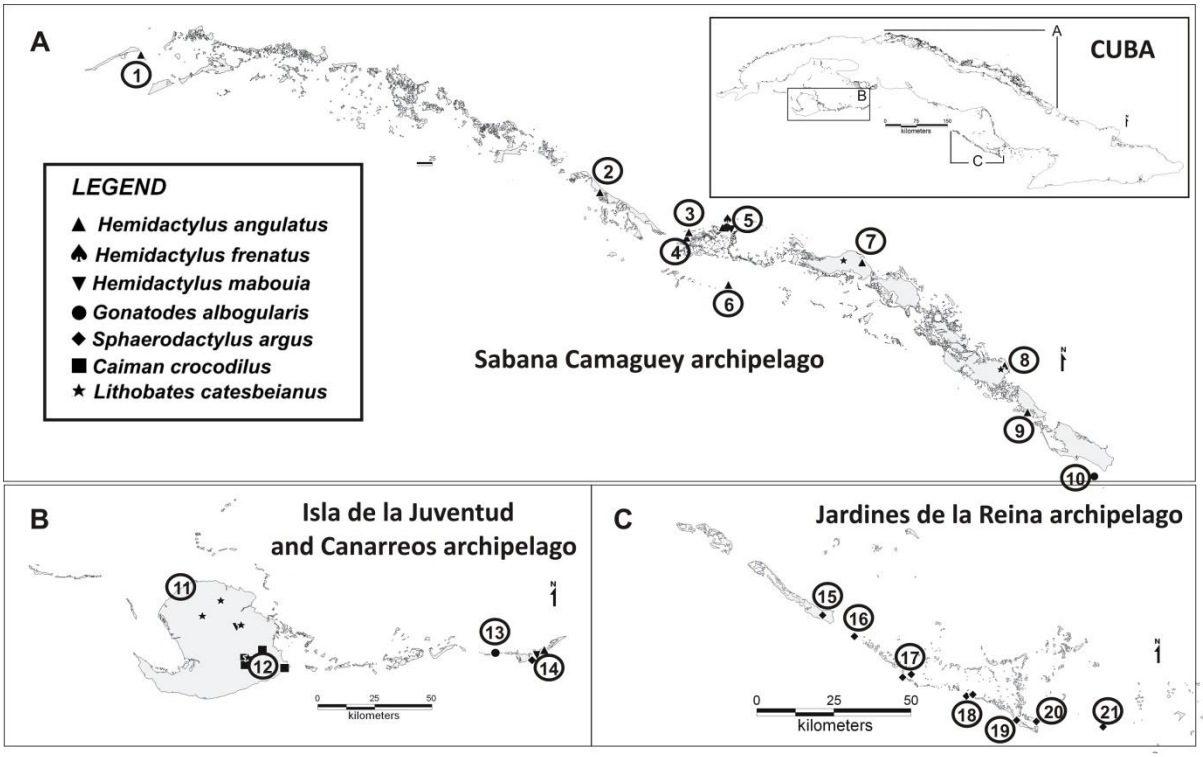

FIGURE 2. Offshore islands and cays of Cuba with introduced amphibians and reptiles. A: Sabana-Camagüey Archipelago; B: Canarreos Archipelago; C: Jardines de la Reina Archipelago. 1. Cayo Buba, 2. Cayo Fragoso, 3. Cayo Francés, 4. Las Brujas, 5. Cayo Santa María, 6. Punta Caguanes, 7. Cayo Coco, 8. Cayo Romano, 9. Cayo Guajaba, 10. Cayos Ballenatos, 11. Isla de la Juventud (Isla de la Juventud), 12. Ciénaga de Lanier (Lanier Swamp), 13. Cayo Rico, 14. Cayo Largo del Sur, 15. Cayo Caballones, 16. Cayo Anclitas, 17. Cayo Cachiboca, 18. Cayo Juan Grin, 19. Cayo Caguama, 20. Cayo Cabeza del Este, 21. Cayo Levisa.

One author (RAB) has observed changes in the vocalization behavior, especially in the duty cycle and call rate of advertisement calls of the endemic Cuban Spotted Toad (*Peltophryne taladai;* Bufonidae) during the vocal interaction with a chorus of up to three or four individual *Lithobates catesbeianus* in at least three localities of the distribution of the toad. The effects of *Lithobates catesbeianus* vocalizations on acoustic communities are expected to be especially severe due to their broad frequency band, which masks the calls of many native species simultaneously (Both and Grant 2012). This species has been reported in many caves in Cuba: Cueva de la Teneria (Armas 1984), where predation on cave fish was observed; Cueva del Agua, in Sagua la Grande, Villa Clara (Armas et al. 1987); Cueva de la Amistad, en Minas de Matahambre and Cueva de las Represas, both in Pinar del Río and Cueva de la Teneria in Mayabeque (Silva Taboada 1988). This species could be a vector for many parasites that could threaten native species and human health. Martínez et al. (1982) identified 12 helminth parasite species (trematodes, cestodes, acanthocephalans, and nematodes) in *Lithobates catesbeianus* collected in Güines, Mayabeque province; Paso Real de San Diego, Sierra del Rosario and Los Palacios, Pinar del Río province; and Santiago de Cuba. Coy and Martínez (1987) found nematodes (*Eustrongylides* sp.*)* in animals collected in Camaguey province. If *Lithobates catesbeianus*is less susceptible to chrytridiomycosis infection than other species, it could be an efficient vector and reservoir for this disease (Daszak et al. 2004; Hanselmann et al. 2004).

The maximum SVL of *L. catesbeianus* is 270 mm (Sampedro et al. 2003). In 1942, the Cuban government promoted production (breeding and propagation) for exportation to the United States as a potential market (MINAGRI 1960). Before World War II, Cuba was an established world exporter for *L. catesbeianus*, but demand was not well established nationally. In North America, reproduction of the species is delayed with a metamorphosis that last approximately 3 y, but this process is completed in only 6 mo with larger animals in Cuba (MINAGRI 1960).

***Rhinella marina*, Marine Toad, Cane Toad, Sapo Gigante, Sapo Marino. Not Established.**

This species is introduced in the Caribbean islands, having been reported for more than 22 islands: Anguilla, Antigua, Aruba, Barbados, Bermuda, St. Vincent and The Grenadines (Mustique, Union Island, Canouan),

Grand Cayman, Dominica, Grenada including Carriacou, Guadeloupe, Jamaica including Cabarita, Hispaniola, Martinique, Montserrat, Puerto Rico (including Culebra), St. Kitts and Nevis, St. Lucia, and the US Virgin Islands (Powell et al. 2011, 2013). In 2013, the species was reported in New Providence, The Bahamas (Virgil, K. 2013. Killer Toad Found in New Providence. Tribune 242. Available from http://www.tribune242.com /news/2013/sep/06/killer-toad-found-new-providence/ [Accessed November 2013]).

There are three different introductions documented from Puerto Rico. The first occurred in 1935, when 14 individuals were sent by G. N. Wolcott from the Insular Experimental Station in Río Piedra, Puerto Rico (Bruner 1935). The animals were released in the Agronomic Station in Santiago de las Vegas, Havana, but without successfully becoming established. They may have been limited by West Indian Mongoose (*Herpestes auropuctatus*) predation, as mongooses were abundant in the Agronomic Station at this time (INIFAT 1946). Mongooses were introduced for biocontrol, especially of insects such as Southern Glass Worms (*Laphygma frugiperda*) and of rodents in the sugar cane crop (INIFAT 1937, 1946).

The second introduction (18 animals) was done by W. C. Hanson, Superintendent of the sugarcane factory Lugareño, Camagüey in 1937. The third introduction (38 toads) was by L. C. Scaramuzza in the sugarcane factories Las Mercedes, Matanzas and Lugareño, Camagüey provinces in 1946 (INIFAT 1937, 1946). All of the introduced animals were from Puerto Rico. The two first introductions were in semi-captive conditions, whereas the third was an intended introduction in many sugarcane crops. No animals have been identified in the wild after these introductions. There are 10 records of this species deposited in two US collections: USNM (six) and AMNH (four), but these records need to be verified because the collection dates in some cases were prior to the first known introduction event and in other cases the locality is ambiguous. It is probable that specimens were mis-identified, being confused with large individuals of *Peltophryne*.

We classify the impact of this species as No Alien populations (NA) because they are not present today. During its ephemeral establishment, the species could compete with the large Cuban toad (*Peltophryne*) species and predate native invertebrates. Eggs, larvae, and secretions of its parotoid glands can be toxic. SVL of *Rhinella marina* is up to 230 mm. There is unpublished information that fire ants (*Solenopsisgeminata* spp.**)** attack adults and young in localities where the species was released (Miguel A. Sosa, pers. comm.).

***Pseudacris crucifer*, Spring Peeper, Not Established.**

This species is not reported currently in other Caribbean islands. The evidence is not clear about the introduction of this species, which was only reported from two localities (Schwartz and Thomas 1975; Schwartz and Henderson 1988, 1991). The introduction may have occurred in the early 20th Century. This species is native from North America (Schwartz and Thomas 1975). Pathways for this species probably include cargo or the plant nursery trade.

No individual has been collected or observed in the last 50 y. Several attempts to locate or collect the species near Marianao, Havana and Canasí, Matanzas provinces by Cuban and foreign researchers have not been successful (Estrada and Ruibal 1999). Its characteristic vocalizations can be used to detect its presence, but these have not been heard.

Because this species has not become established, we classify its impact as No Alien populations (NA). The average SVL is 32 mm (Schwartz and Henderson 1991). There is contention as to the accuracy of the collection records of this species in Cuba. Consequently, this species has not been included in the recent list of Cuban amphibians. We were not able to find reports of Cuban specimens in several online databases of museums and herpetological collections in the US.

***Hoplobatrachus tigerinus*, Indian Bull Frog. Transported.**

The species is not reported for other Caribbean Islands. According to the Centro Nacional de Seguridad Biológica, Havana, Cuba, this species was introduced on May 2002, and placed in the Aquaculture Center (Mampostón), Cotorro, Havana province. It came from Thailand for aquaculture and food purposes.

At present, this species is found in captivity as an experiment for future economic exploitation in Mampostón. As animals in the wild have not been reported the classification of impact is No Alien populations (NA). The SVL is up to 170 mm (AmphibiaWeb. 2015. *op. cit*.). Because *Lithobates catesbeianus* have never been favored for consumption by Cubans, we consider that projected consumption of this similar species is not a justification for its introduction. Information on population size is not available, but the species has the potential to negatively affect local species by predation and competition with the local frog fauna, as has been suggested in other island ecosystems (Harikrishnan and Vasudevan 2013).

***Other transported amphibian species.*—**Powell et al. (2011) referred to six hylid frogs of the genus *Osteocephalus* (non-native to Cuba) that were also transported from Cuba to the US in 2008. Additional information on this case is not available (Christina M. Romagosa, pers. comm.). Based on Powell et al. (2011), this is the first information of the presence of this non-native genus in Cuba.

Caiman crocodilus. **Spectacled Caiman, Babilla, Caimán de Espejuelos (Fig. 1B). Invasive.**

This species is found on the main island of Puerto Rico, Vieques Island, Carriacou (Grenada), and Isla de San Andrés, Colombia (Powell et al. 2011). This species was introduced in 1959 at Lanier Swamp, Isla de la Juventud. Previously, the animals were in captivity in the Fluvial Repopulation Center El Dique in Havana (Varona 1976). Escobar (1995) stated that the species was introduced between 1962 and 1964. Nine animals (Varona 1980) were introduced from Colombia (Escobar 1995). This species is used for food and there is commercial exploitation for hide and meat in order to reduce the exploitation and hunting of Cuban Crocodiles, *Crocodylus rhombifer* (Berovides et al. 2000).

Luis Moreno (pers. comm.) noted that the introduction to the wild occurred after an intensive rainy episode that took place in the Isla de la Juventud in 1959. According to Dunn et al. (1959) and Gelhard (1959), tropical storm Judith affected the western Caribbean from 17–21 October 1959, and the track of the storm was near the Isla de la Juventud. The intensity of this storm likely caused flooding, facilitating the release of some individuals from captivity and dispersing them to areas suitable for reproduction and survival. Rodríguez Soberón et al. (1996) suggested that the decline of the *C. rhombifer* population in Isla de la Juventud was due to human exploitation and led to the *Caiman crocodilus* introduction. This species has a wide distribution across the Isla de la Juventud. It is more abundant in the northern part of the island and in the eastern part of Lanier Swamp, animals have been found in rivers, dams, ditches, drains, sewers, and wetlands (Alonso Tabet et al. 2014). The population estimate is over 40,000 individuals (Rodríguez Soberón et al. 1996; McMahan et al. 1998). Several individuals have been sighted around the Cayo Potrero farm, in large ponds such as Laguna Grande and Laguna Redonda, Lanier Swamp, and also Punta del Este (Fig. 2). There are two doubtful records of *C. crocodilus* (1912 and 1955) in the Carnegie Museum (CM) and Kansas University (KU) collections, but these dates are older than the recognized first introduction.

We classify their impact as Moderate (MO). The species may cause depredation on endemic freshwater fishes, such as the Cuban Gar or Manjuarí (*Atractosteus tristoechus*), crustaceans, mollusks, reptiles, aquatic birds, and other taxa (Escobar 1995). It is also in competition with two native crocodiles (the American Crocodile, *Crocodylus acutus*, and *C. rhombifer*), and may cause hatchling depredation (Varona 1980). Alonso Tabet et al. (2014) do not recognize negative impacts on the reintroduced *C. rhombifer* population in Isla de la Juventud.

We have taken all the following biological information from Rodríguez Soberón et al. (1996) and Alonso Tabet et al. (2014). The species reaches a maximum size of 225 cm, with an average of 125–175 cm for adults and with males larger than females. It has a generalist diet, with feeding based on fishes, crustaceans, amphibians, aquatic birds, and juveniles of other crocodiles. Its interaction with Cuban crocodiles (*Crocodylus acutus* and *C. rhombifer*) has been poorly studied. It has a greater reproductive potential than the Cuban Crocodile. Females reach sexual maturity around 5-y old, with a size of 1.2 m, and males reach sexual maturity at 1.4 m. The fecundity rate is high (about 100 eggs/nest). Several females may share the same nest, increasing the hatching rate success to 95%. In contrast, the Cuban Crocodile reaches sexual maturity at about 6 y and 1.8 m length, has a lower fecundity rate (2–33 eggs/nest), and has only a 50% hatching success rate (Rodríguez Soberón et al. 1996).

Hemidactylus angulatus, **Salamanquesa (Fig. 1C). Invasive.**

This species is found on Hispaniola, including Saona Island (Dominican Republic), the main island of Puerto Rico, and the Mona and Vieques islands (Powell and Maxey 1990; Henderson and Powell 2009). This species was first reported in Cuba by Barbour (1935), but without a specific locality. It has historically been confused with *H. mabouia* (Kluge 1969) and its introduction date is uncertain. There are two alternative possible population sources: it may have arrived from West Africa with the slave trade or from Hispaniola, where it was previously detected by Barbour (1930). The pathway was via cargo. It is easily transported with merchandise and construction materials.

This species was presumably introduced to the Caribbean islands accidentally in ships from Africa during the period of slavery. Over-water dispersal has been suggested to some Antillean islands (Kluge 1969). Early records for the species are from coastal or harbor zones (see map in Schwartz and Henderson 1991). Barbour (1930) does not include it as introduced in Cuba, only for Hispaniola. Later, he recognized it as an introduced species in Cuba (Barbour 1935, 1937). Buide (1967) and Garrido and Jaume (1984) listed this species in their catalogs, but did not recognize it as an introduced species. It is currently the most abundant and widely distributed *Hemidactylus* in Cuba, being very common in several Cuban cities (Rodríguez-Schettino et al. 2013; Díaz, 2014), and is also known from some small islands and cays (Estrada, 2012). Garrido et al. (1986) gave the first report of this species for offshore islands (Cayo Guajaba). Rodríguez-Schettino and Rivalta (2003) gave a wider distribution range than *H. mabouia*, including the Canarreos and Sabana-Camagey Archipelagos, but they did not identify islands. Estrada

(2012) described the distribution in the following islands and cays of Cuba: Buba, Caguanes, Fragoso, Francés, Santa María, Coco, Romano, Guajaba, and in the Sabana-Camaguey archipelago (Fig. 2). In May, 2013, the species was also observed in Cayo Largo del Sur, Canarreos archipelago (Fig. 2). Rodríguez-Schettino et al. (2013) mentioned that the species was listed in six management plans of Cuban protected areas. However this review identifies its presence in 19 Cuban protected areas (Appendix 1). CZACC hosts 144 specimens collected in seven provinces, but the species is known also from the remaining seven Cuban provinces, including Isla de la Juventud (Díaz, 2014). There are additionally 56 specimens deposited in four US collections: AMNH (38), LACM (11), USNM (six), and UMMZ (one) from six Cuban provinces (Artemisa, Havana, Matanzas, Camaguey, Holguín and Guantánamo, but several records are ambiguous with vague descriptions such as Location: Cuba).

We classify the impact as Minor (Mi)**.** Two of us (RBP and RAB) witnessed two types of uncommon conflicts in Cuba: the excrement of this species causing spotting on walls in buildings and some human phobias to reptiles in hotels and houses. The mean SVLs are 71 mm in males and 68 mm in females. It is an evasive species with nocturnal activity and feeds on small non-flying arthropods such as cockroaches, spiders, and pill bugs (Iturriaga and Marrero 2013). It is a cryptogenic species that is sometimes considered erroneously as native in lists and catalogs, although the historical records are deficient. It was formerly known as *H. brookii*, *H. brookii haitianus*, or *H. haitianus* (Buide 1967; Kluge 1969; Garrido and Jaume 1984; Schwartz and Henderson 1991; Henderson and Powell 2009; Estrada 2012). It has possibly been mis-identified and is confused with *H. mabouia* (Kluge 1969). The genetic similarity between the two examples of *H. h. haitianus* from Cuba (Matanzas province) and a specimen of *H. angulatus* from the Gulf of Guinea, together with the morphological similarity between animals from the two areas, suggest that *H. haitianus* may not deserve a specific separation (Carranza and Arnold 2006). This finding was confirmed later by Weiss and Hedges (2007), who used this evidence to explain the arrival of this species to the Caribbean islands during the period of the slave trade, and also by Gamble et al. (2011), who analyzed the patterns of New World gecko origins. However, Kraus (2009) does not include this species as introduced in Cuba. We have observed this species living in constructions and buildings in false ceilings, in cracks in windows and walls, and in areas under wood, crockery, and rubble. The eggs are very tolerant to salinity and the female can retain sperm for several weeks, which can favor overseas dispersion and colonization (Kluge 1969).

***Hemidactylus mabouia*, Wood Slave, Salamanquesa (Fig. 1D). Invasive.**

This is the most widely distributed house gecko within the Caribbean islands. Powell et al. (1998) noted its presence in 68 islands in the Caribbean, but Powell et al. (2011) only listed 12 islands. The distribution range compiled in this review includes more than 100 islands (Schwartz and Henderson 1991; Powell et al. 1998; Henderson and Powell 2009; Kraus 2009; Powell et al. 2011): Anguilla, Antigua and Barbuda including Redonda and Great Bird Island and their satellite islets, Aruba, Bahamas (in Exuma islands and New Providence), Barbados, Bonaire, Klein Bonaire, Cuba, Curacao, Grand Cayman, Dominica, Guadeloupe and its satellites Île Pigeon du Nord, Tête a l'Anglais, Îles de la Petite Terre (Terre de Bas) and Îles de Saintes (Île a Cabrit, Terre-de-bas, Terre-de-haut), Hispaniola, Jamaica, Martinique, Montserrat, Puerto Rico (in Vieques, Culebra, Mona, Cueva, Cayo de Tierra and almost in all 34 adjacent islets), St. Kitts and Nevis, St. Eustatius, St. Lucia, St. Martin, Turks and Caicos (in South Caicos Island and Grand Turk), Saba, US and British Virgin Islands (St. Thomas including Fish Cay, Hassel Island, St. John's including Lovango Cay and Henley Cay and Sandy Cay, Jost Van Dyke, Guana Island, Tortola Island including Sandy Cay, Bellamy Cay, Frenchman's Cay, Beef Island, Marina Cay, Peter Island, Salt Island, Cooper Island, Virgin Gorda, Anegada, and St. Croix), St. Vincent and The Grenadines (Bequia, Petite Martinique, Mayreau), Grenada, including Carriacou, and Trinidad and Tobago (several satellite islands, including Carrera, Chacachacare, Nelson, and Patos).

It was probably introduced in the early 16th Century with the beginning of slavery in Cuba in 1515 (Pichardo 1965). However, the first report of this species in Cuba is Cocteau and Bibron (1843), who referred to it as native. It came from Western Africa (Kluge 1969). The pathway probably was via cargo. This species is easily transported with merchandise and construction materials.

It was introduced accidentally with other maritime trade from Africa after the 16th Century. Some insular populations in the Caribbean may have arrived via natural over-water dispersal from South America or Africa (Powell et al. 2011). Based on the historical record, it appears to be the first introduced *Hemidactylus* in Cuba. We consider that it was the most abundant and widely distributed *Hemidactylus* in Cuba until the 1950s, and its former distribution records appear to be associated with harbors. Barbour (1930, 1935, 1937) and later Buide (1967) recognized it as introduced and with very local distribution in Cuba. The current distribution in Cuba is spotty but not completely known. Gundlach (in Poey 1851) reported it for the Isla de la Juventud (Fig. 2) and as very common in Havana, Sierra Rangel in Pinar del Río and Cabo Cruz in Granma

(Gundlach 1866–1868). Barbour and Ramden (1919) reported the Gundlach (1880) information and added Mariel in Pinar del Río, Matanzas, and Santiago de Cuba. However, Kluge (1969), Garrido and Jaume (1984), Schwartz and Henderson (1991) and Powell et al. (1996) considered that the Greater Antillean records were isolated occurrences and reported the presence of the species for Guantánamo city. These historical records provide information of its presence in Pinar del Río, Havana, Isla de la Juventud, Matanzas, Granma, Santiago de Cuba and Guantánamo provinces, but no offshore island or cay was included other than Isla de la Juventud. Rodríguez-Schettino et al. (2013) and Díaz (2014) compiled information of Cuban distribution of this species, but both omitted some historical data (e.g., Rangel, Mariel, Isla de la Juventud, Cabo Cruz). We have observed *H. mabouia* in houses in La Víbora and Víbora Park areas, both in Havana city, and also in Cayo Santa María, North of Villa Clara in August, 2011 and Cayo Largo del Sur, Canarreos Archipelago in May 2013 (Fig. 2). Although only one specimen (from Santiago de Cuba) is deposited in CZACC, other identified specimens as *Hemidactylus* sp. could be assigned to the species, therefore specimens deposited in this collection need revision. There are three specimens in MNHNCu. There are additionally 77 specimens deposited in five US collections: USNM (37), KU (20), MCZ (nine), SDNHM (eight) and MPM (three). Most of these specimens are from the Guantánamo US Naval Base. This species has been reported in only one management plan of Cuban Protected Areas: from the Management Floristic Reserve San Ubaldo-Sabanalamar in Pinar del Río province (Appendix 1).

We classify the impact as Minor (Mi). It probably competes with other small reptiles, such as *Sphaerodactylus* species that live associated with human constructions. It has similar impacts to that of *H. angulatus***.** Martínez Rivera et al. (2003) reported *H. mabouia* in Cuba as a host of the ectoparasite *Geckobia hemidactyli* that is also an introduced species.

The mean SVL is 68 mm in males and 61 mm in females. It has nocturnal activity and feeds on small insects and is attracted by artificial light (pers. obs.). The genetic uniformity of *H. mabouia* across its worldwide distribution indicates rapid and recent dispersion, most likely with human intervention (Carranza and Arnold 2006; Gamble et al. 2011). We have found it to be common in houses, hotels, and other buildings where it inhabits false ceilings, cracks of windows and walls, and areas underneath wood, crockery, and rubble. The female can retain sperm for several weeks (Kluge 1969), facilitating overseas dispersion and colonization.

***Hemidactylus frenatus*, Common House Gecko, Salamanquesa. Invasive**.

This species is known from other Caribbean islands only from the main island of the Dominican Republic (Scantlebury et al. 2010). In Cuba it has been found at the US Naval Base at Guantánamo Bay (Powell et al. 2011). Díaz (2014) reported it also from Cayo Santa María, Sabana-Camaguey archipelago. The source is unknown but its native range is tropical Asia and the Indo–Pacific (Case et al. 1994).

Two probably independent introductions occurred in the mentioned localities. The species probably stowed away in a variety of cargo shipments or the containers that entered the US Navy Base in Guantánamo. Díaz (2014), however, suggested that the presence of *Hemidactylus frenatus* in Cayo Santa María is due to the importation of building materials or shipments of lumber, similar to the proposal of Powell (2004) for the other introduced ranges of this species. We consider that the development of the tourism industry, the continued traffic toward this beach destination, and the plant nursery trade could be additional ways to transport the adult or eggs of this species to the cay. Nine voucher specimens are deposited in MNHNCu (5060-5068). There are additionally 11 records in MCZ, all from the US Naval Base in Guantánamo Bay.

We classify the impact as Data Deficient (DD). While the impact of the gecko has not yet been studied closely, it has been identified as a generalist predator that competes, replaces, and causes local extinction of native geckos on other islands (Case et al. 1994; Cole et al. 2005). Díaz (2014) extrapolated possible patterns of displacement and replacement among introduced geckos in Cuba. Although these assertions are reasonable, evidence is presently lacking and further sampling is needed. Their presence in hotels can produce conflict with tourists who have phobias related to reptiles, and also as the excrement of this species can produce spotting on walls in hotels and houses. These geckos generate damage to the air-conditioning units throughout its native and introduced range (Chang et al. 2013), but this impact has not been reported in Cuba.

Hemidactylus frenatus are 75–150 mm SVL with male larger than females (Invasive Species Specialists Group (IUCN). 2015. *op. cit*.). Díaz (2014) reported that it was locally abundant in the Hotel Husa, Cayo Santa María, Villa Clara province. However, there are no other records reported for nearby hotels or other tourism facilities on Cayo Santa María. Females have a capacity of long-term sperm storage (Murphy-Walker and Haley 1996) that could favor dispersion and colonization success.

***Hemidactylus turcicus*, Mediterranean House Gecko, Salamanquesa. Not Established.**

In the Caribbean islands, this species is only found in Puerto Rico (Powell et al. 2011). McCoy (1970) considered as the first record for Cuba, a specimen collected in Matanzas by Barbour and Ramsden (1919) that was misidentified as *Hemidactylus mabouia*. Barbour (1930) does not refer to it as living in Cuba; however, Stuart (1934) referred to information from Barbour that indicated that the species was established in Cuba. In Barbour (1935, 1937), it is included as introduced. Previously, Leavitt (1933) considered his finding at Central Soledad, Cienfuegos, as the first report in Cuba in August 1932 (MCZ 34257).

Leavitt (1933) mentioned the possibility that it was introduced via Key West, Florida, USA. Other possible sources could be Spain or the Canary Islands, but the specific origin is unknown. Powell et al. (2011) consider that the origin of the Cuban population of this species is unknown. The pathway for arrival probably was via cargo, as for other introduced *Hemidactylus* spp.

It could have been locally invasive. However, it was a very rare species. Leavitt (1933) noted that it was not present in Havana. Barbour (1935, 1937) recognized it as an introduced species. Buide (1967) included the species in his catalog, but like Garrido and Jaume (1984) did not recognize it as an introduced species. Garrido and Jaume (1984) reported their distribution as a series of coastal harbors between Havana and Santiago de Cuba. Schwartz and Henderson (1991) identified its distribution as the cities of Havana, Matanzas, Villa Clara, Cienfuegos, Sancti Spíritus, Santiago de Cuba, and Guantánamo, mainly in harbor zones or with intense urban activity areas. There are only two specimens in the collection of the Institute of Ecology and Systematics (CZACC-9804, 9811), both from Havana city. For > 50 y this species has not been observed in any Cuban locality, the last record in CZAAC was date in 1956, while one specimen from Havana was collected in 1957 and deposited in the USNM, Smithsonian Institution, Washington, D.C. There are additionally 12 other records in US collections: USNM (four), AMNH (four), MCZ (three), and UMMZ (one). This gecko is only reported for one Cuban protected area (Appendix 1), but this record requires verification.

We classify the impact as No Alien populations (NA) today. In the past, it was probably a competitor with native species (principally *Sphaerodactylus* species) for space and other resources. Probably this animal could have similar conflicts with the other invasive *Hemidactylus* spp. It reaches sizes up to 55 mm SVL, but Garrido and Jaume (1984) noted the size can attain 90 mm SVL. The principal habitats are buildings and any edification structures.

***Gonatodes albogularis fuscus*, Yellow-Headed Gecko, Salamanquita de Cabeza Mostaza (Fig. 1E). Invasive.**

This species is found in Aruba, Curacao, Hispaniola (in Haiti including Île de la Gonâve and in the Dominican Republic in Isla Cabritos), Jamaica, and Grand Cayman (Schwartz and Henderson 1991; Lever 2003; Kraus, 2009; Powell et al. 2011). Introduction in Cuba may have occurred in the 18th Century through Havana and Santiago de Cuba harbors. The first report of this species in Cuba is by Cocteau and Bibron (1843), who referred to it as native. Their original distribution is Central and South America (Schwartz and Henderson 1991). The pathway probably was via cargo.

Gundlach (1866–1868) reported it only for Havana and later for Santiago de Cuba harbors (Gundlach 1880). It is frequently found in harbor zones such as Havana, Batabanó, Mariel, Santiago de Cuba, Nipe and Guantánamo (Barbour and Ramsden 1919; Garrido and Jaume 1984), but now has a wider distribution in inland Cuba such as Marianao, Cotorro and Santiago de las Vegas in Havana; Santo Domingo, Villa Clara, and also in Holguín city (Garrido and Jaume 1984). Rodríguez-Schettino et al. (2013) recognized its presence in all Cuban provinces, except Cienfuegos. Estrada (2012) reported this species from some cays in northern Cuba, such as Santa María, Villa Clara, and Ballenatos, Camaguey (Fig. 2). In May 2013, in a rustic restaurant in Cayo Rico, east of Cayo Largo del Sur (eastern Canarreos Archipelago), two employees informed one of us (RBP) about its presence in the cay (Fig. 2), probably introduced with guano, wood, and construction material to build the rural installation. Rodríguez-Schettino et al. (2013) noted that the species is included in five management plans of Cuban protected areas. However our review of these plans showed its presence in 10 Cuban protected areas (Appendix 1), but it has not been considered as an introduced species. There are 120 specimens in CZACC, collected from eight Cuban provinces. There are 184 records in nine US collections: AMNH (92), USNM (48), MCZ (nine), LACM (nine), KU (eight), ANSP (eight), FLMNH (seven), TCWC (two), and UMMZ (one). However, several of these records lack information on exact locality and date of collection.

We classify the impact as Minimal (ML). It probably competes with native species such as *Sphaerodactylus* spp. The SVL of *Gonatodes albogularis fuscus* is 40 mm. Males length is 34.3 mm SVL from 3 mo to 1 y, and females are 39 mm within 6 mo to 1 y (Díaz 2008). The species is distributed in urban and rural areas (indoor and outside of houses) and in nature also. Cryptogenic species are sometimes considered erroneously as native in lists and catalogs and with historical records before 18th Century. Gundlach (1880) did not refer to the species as introduced. Other catalogs refer to the unclear situation about the species status but

consider it as introduced because the Cuban animals are morphologically similar to those of Nicaragua (Barbour 1914; Barbour and Ramsden 1919). More recently, Schwartz and Henderson (1991), Lever (2003) and Henderson and Powell (2009) did not consider it as introduced in Cuba. Kraus (2009) did not include as introduced in Cuba, and Powell et al. (2011) consider the species natural distribution in Cuba as doubtful. By contrast, some authors have ratified the invasive status of the species in several Caribbean islands, including Cuba (Thomas 1975; Powell et al. 2011). As with Crombie (1999) for Jamaica and Hispaniola, we suggest that the early distributional records around major harbors is consistent with human mediation. However, phylogeographical and divergence time studies are needed to explain the origin of this species in Cuba. It is a diurnal animal and is easily detected in shadows and wet places, associated with houses, construction, walls, and among roots and the bark of large trees such as *Ficus* spp. in urban parks (Martínez Reyes and Hernández Marrero 2003). Depredation by English House Sparrows (*Passer domesticus*) has been observed (Bello 2000). Females store sperm and can connect infertile eggs with sperm retained for months (Luis Díaz, pers. comm.), a process that increases its dispersion and invasive capacity.

***Sphaerodactylus argus*, Ocellated Gecko, Salamanquita (Fig. 1F). Invasive.**

This species is found in the Bahamas in North Bimini island and New Providence island (Thomas 1975). Introduction in Cuba possibly occurred in the 18th century through Santiago de Cuba harbor. It probably came from Jamaica via cargo.

The limited population and few reports in the 19th Century, and their southern pattern of distribution in Cuba in coastal and harbor zones for many years, justify a possible human introduction. The animal is easily dispersed in building materials, wood, trunks of *Cocothrinax* and *Thrinax* palms, and commercial trade. Overseas dispersion has been suggested also as a means of introduction (Powell et al. 2011). Gundlach (1880) considered it very rare and found only in Santiago de Cuba on two occasions. Barbour (1914) reported it from Cienfuegos and Jiguaní, Grant (1957) from Soledad Botanical Garden (Cienfuegos) and Ruibal (1959) from Santa Cruz del Sur, Camagüey. Thomas (1975) indicated its presence from Cuba and its offshore islands and cays, Cayo Cabeza del Este in the Jardines de la Reina and Cayo Levisa near Santa Cruz del Sur (Fig. 2). Garrido and Jaume (1984) identified additional localities: Cienfuegos, Juraguá, Pasa Caballos (Cienfuegos province); San Blas (Sancti Spíritus); Santa Clara (Villa Clara); Los Negros, Jiguaní, Belic, Cabo Cruz (Granma); Santiago de Cuba and in the cays of Caguama (= La Tronconera), Cachiboca, Juan Grín and a cay east of Cabeza del Este (Fig. 2). In the south coast and eastern Cuba, it has been reported from Santiago de Cuba Bay, Cabo Cruz, south Camagüey and Las Tunas, Cienfuegos Bay, Playa Girón, and other keys of Jardines de la Reina Archipelago such as Anclitas and Caballones (Schwartz and Henderson 1991; Estrada 2012; Rodríguez-Schettino et al. 2013). In 2013, one of us (RBP) observed it also in Cayo Largo del Sur, Canarreos archipelago (Fig. 2). The species is present in six protected areas, but erroneously has been considered native (Appendix 1). There are 16 specimens in CZACC, collected from four provinces including some offshore islands. There are additionally 136 records in US collections: CAS (87), MCZ (29), AMNH (10), USNM (seven), FLMNH (two), and UMMZ (one), but more than half of the records do not have precise locations.

We classify the impact as Minimal (ML). It probably competes with native *Sphaerodactylus* spp. The maximum SVL is 33 mm. This is a cryptogenic species occurs in lists and catalogs and with historic records deficient before the 18th Century. It is very common in Jamaica (Thomas 1975; Schwartz and Henderson 1991). Barbour (1914) and Buide (1967) considered it an introduced species. Thomas (1975) considered that Cuban and Bahaman specimens fall within the range of variation in pattern of the western Jamaican population. As noted by Thomas (1975), natural arrival or human mediation cannot be stated with certainty, and its distribution is not completely known. It occurs on ridges and along beaches, in limestone xeric scrubs, in houses and hotel rooms, pastures, *Acacia* woods, and *Cocos* groves, specifically under the bark of trees, in and under logs, under *Agave* and cacti fragments, in large termite nests on the ground, in piles of *Cocos* husks, trash, rocks, limestone rubble, palm trash, and occasionally in dry bromeliads, from ground level to almost 5 m in trees (Schwartz and Henderson 1991).

***Agama* cf. *agama*, Common Agama. Not Established.**

No current range has been reported for other Caribbean islands. In February 1991, five individuals were collected in Havana harbor aboard a ship from Ghana (MNHNCu collection). The first published note appeared in a Juventud Rebelde, a Cuban newspaper in 1995, when the species was sighted in Cienfuegos harbor (Gonzalo, unpubl. report). It probably came from Ghana via cargo as pathway.

Specimens were collected in Havana harbor by Alfonso Silva and Riberto Arencibia (National Museum of Natural History of Cuba) during 1991, and deposited in the herpetological collection (MNHNCu 3446-3450) in 1991. In March 1996, two additional animals were collected by Vicente Berovides (University of Havana) in Cienfuegos harbor (MNHNCu 4349-4350). Evidence does not exist on any relationship among the animals of

both harbor localities (Havana and Cienfuegos), but it could be possible that there were two independent introduction events. It became invasive when it became established in the wild. Animals were established as a population for many years around Cienfuegos harbor. Surveys carried out by the authors during 2012 and 2014 years in the surroundings of Cienfuegos harbor did not detect the species. However we do not discount the possibility that the species has been transferred to other areas in Cienfuegos province. Local people around Cienfuegos harbor have provided information on House Cat (*Felis silvestris catus*) depredation on adults and Smooth-billed Ani (*Crotophaga ani*) depredation on juveniles (Orlando H. Garrido, pers. comm.).

We classify the impact as No Alien populations (NA) because no individuals have been identified since 1996. In the past, competition with native lizards and saurophagy had been observed in the Brown Anole (*Anolis sagrei*) and the Cuban Green Anole (*A. porcatus*), as well as fighting and displacing of Northern Curly-Tailed Lizards (*Leiocephalus carinatus*; Luis Moreno, pers. comm.; Gonzalo, unpubl. report.). The SVL of this species is around 30 cm, according to a newspaper note (Gonzalo, unpubl. report). While this species could be confused with *Leiocephalus carinatus*, the color is different. Additionally, *Agama agama* has a more robust body and powerful dentition.

***Gymnophthalmus underwoodi*, Underwood's Spectacled Tegu (Fig. 1G). Invasive.**

This species is found in Antigua and Barbuda, Barbados, Dominica, Grenadines (including Bequia and Union Island of St. Vincent and The Grenadines), St. Vincent, Grenada (including Hog Island), Guadeloupe (including Grande-Terre), La Désirade, Marie-Galante, Martinique, St. Christopher (St. Kitts), St. Martin/St. Maarten, US Virgin Islands (St. Thomas), Trinidad and Tobago (Lever 2003; Powell et al. 2011, 2013), and Hispaniola (Scantlebury et al. 2010). The first collection record in Cuba corresponds to one individual (BSC.H 3574) deposited in the herpetological collection of the Eastern Center for Ecosystem and Biodiversity in Cuba from the immediate vicinity of Santiago de Cuba harbor, collected by Lionis Milián (Eastern Center for Ecosystems and Biodiversity) in 2007. Their population source is unknown, probably from South America (Alfonso et al. 2012). The pathway was cargo as accidental introduction via shipments (Alfonso et al. 2012).

Subsequent records are from the garden of the José Martí Urban Center, in September 2008 (BSC.H 3575), from a backyard in the Vista Alegre area, Santiago de Cuba city collected by Freddy Rodríguez (Eastern Center for Ecosystems and Biodiversity) in October, 2011 (BSC.H 3576), and another individual in December 2011 without exact locality data in Santiago de Cuba city. The first published reports are in 2012 from individuals collected also in 2011 near the student residence of the University of Oriente, Santiago de Cuba province, where it has established (Alfonso et al. 2012). Its density is presently unknown. This species is well adapted to disturbed habitats, and appears to have rapidly spread through much of Santiago de Cuba city (Alfonso et al. 2012). There are five specimens in MNHNCu and four in BSC.H.

We tentatively classify the impact as Data Deficient (DD), but it could compete with native species. The mean SVL is 36.3 mm for animals collected in Cuba (Alfonso et al. 2012). The species is unisexual (only females) and parthenogenetic (Hardy et al. 1989), which facilitates colonization as single individuals can establish new populations. Habitats are sunny places with withered leaves, gardens, building places, and agricultural zones (Alfonso et al. 2012).

***Iguana iguana*, Green Iguana. Transported.**

This species is found in Anguilla, Antigua and Barbuda, The Bahamas, British Virgins Islands, Grand Cayman, Guadeloupe, Grenadines, Grenada, Les Iles de Saintes, Maria Galante, Martinique, Montserrat, Puerto Rico (including Icacos), Colombia (San Andrés and Providencia), St. Barthélemy, St. Croix, St. Lucia, St. Martin, St. Maarten, St. Vincent, Turks and Caicos, Saba, Swan Islands, and US Virgin Islands (Schwartz and Henderson 1991; Kraus 2009; Powell et al. 2011, 2013). Moreover, Lever (2003) reported the species in St. Christopher (St. Kitts) and Anguilla (where 15 animals were eradicated when they arrived from Guadeloupe after hurricanes in 1995). The introduction date, place and population source are unknown. The probable pathway is as pet trade by private individuals.

We classify the impact as No Alien populations (NA), but more research is needed. No animals are reported in the wild. The few reports are from animals introduced as pets. We know only one individual in private captivity in a backyard in Víbora area, Havana city. Adult SVL to 500 mm. The species is used globally as pets and for food (Henderson and Powell 2009) First introductions were for food in the pre-Columbian era by Amerindians and by the first colonialists in some Caribbean islands (Powell et al. 2013).

***Indotyphlops braminus*, Brahminy Blind Snake. Invasive.**

In the Caribbean islands, these snakes have been reported from Anguilla, Aruba, St. Christopher (St. Kitts), Barbados, Guadeloupe, Mustique (St. Vincent and The Grenadines), the Turks and Caicos, Curaçao, and St. Eustatius (Powell et al. 2011). The species is the most widely distributed snake on earth (Díaz and Cádiz 2014). In Cuba all known individuals were collected in

July 2014, in at least two localities in Havana province (Díaz and Cádiz 2014). The population source is unknown. Powell et al. (2011) suggest that other Caribbean islands populations might have been introduced from Florida. The pathway is the plant nursery trade (Díaz and Cádiz 2014).

Three living adults were collected in Loma del Burro in 10 de Octubre municipality, Havana city (MNHNCu 5071-3). One month later one desiccated individual was seen but not collected in the same locality. Another specimen (MNHNCu 5074) was collected also in July 2014 in Playa municipality of Havana city (Díaz and Cádiz 2014). This recently discovered species probably has a wider distribution given its pathway, but it is a secretive species living underground, and not easy to detect. We classify the impact as Data Deficient (DD). This is a parthenogenetic species with unisexual reproduction (Díaz and Cádiz 2014), which facilitates dispersion and colonization because single individuals can establish new populations.

***Chelonoidis carbonarius*, Red-Footed Tortoise, Morrocoyo, Tortuga de Patas Rojas (Fig. 1H). Established Non-invasive.**

This species is found in Anguilla, Antigua and Barbuda, Barbados, Dominica, Grenada, Grenadines (including Canouan and Union Island of St. Vincent and the Grenadines), Martinique, St. Barthélemy, Montserrat, Nevis, St. Christopher (St. Kitts), St. Lucia, St. Eustatius, St. Martin, St. John's, Lovango Cay, St. Croix, St. Peter, St. Thomas, San Andrés, Water Island, Tortola, Virgin Gorda (Virgin Islands), Windward Islands, and Puerto Rico (Censky 1988; Lever 2003). Powell et al. (2011, 2013) only refer to Barbados, Saba, St. Barthélemy, St. Christopher (St. Kitts), and St. Eustatius. In Cuba, introductions occurred in the the 18th and 19th centuries and the authors (RBP and RAB) also know of illegal introductions around 2005 and later. The probable population sources for the first introductions were from South America or other Caribbean islands, but the recently introductions were from Venezuela. The pathway for the first introductions were probably for use as food, especially the eggs; more recent introductions were for use as pets by private individuals. All recent introductions have taken place via airports, hidden in pockets of travelers.

The first introductions in the Caribbean Islands, probably also in Cuba, were by Amerindian and early European settlers (Censky 1988). It is possible that some individuals belonging to this species could have been held in captivity some years ago. Currently, it is only found in captive conditions. Seven individuals of this species have been observed by the authors: on July 2013, we observed an 8-y old animal in the Fontanar area, Havana cit; we found another four animals living in captivity in Martí, Matanzas province in 2014; and in 2015, we sighted two animals in Lawton, Havana province and Corralillo, Villa Clara province, respectively.

We classify the impact as No Alien populations (NA). The species reaches a CL of 60 cm in males and 40 cm in females. In Cuba, the status of this species is not clear and some animals perhaps have been considered as *C. denticulatus*. Gundlach (1880) refers to some characters belonging to this species in animals that he maintained in captivity in 1844. This species is more common as a pet than *C. denticulatus* and has a significant introduction history in the Caribbean (Censky 1988).

***Chelonoidis denticulatus*, Yellow-Footed Tortoise, Morrocoyo, Tortuga de Patas Amarillas (Fig. 1I). Established Non-invasive.**

This species has been reported in Guadeloupe, Hispaniola, Providencia (Colombia), Jamaica, Puerto Rico, St. Christopher (St.Kitts), St. Lucia, St. Vincent (Censky 1988). However, Powell et al. (2011, 2013) referred the species only for Guadeloupe. This species has been present in Cuba with certainty from the early 19th Century but perhaps from late 18th Century. Gundlach (1880) had some individuals in his garden from 1844 and it was a common animal in Cuban gardens at this time. Barbour (1914) referred to several records from Cuba. Censky (1988) reviewed the literature about *Geochelone* (now *Chelonoidis*) and considered this species to be present in Cuba based on reports from the 20th Century (Barbour 1914; Grant and de Sola 1934; Buide 1967). Probably several introductions as pets have occurred during the last two centuries. It came from South America and most recent introductions from Venezuela specifically. The pathway for first introductions probably was for food (meat and eggs) and for the pet trade by private individuals later.

The first introductions in Caribbean islands were by Amerindian and early European settlers (Censky 1988); probably those occurred also in Cuba. The first reference of this species in Cuba is from Rodríguez-Ferrer (1876). Luis V. Moreno (pers. comm.) considered that this turtle lived in the wild around Moa and Baracoa, Holguín and Guantánamo provinces, but no voucher specimens have been deposited in collections. In 2013, the authors (RBP and RAB) observed animals from an illegal introduction living as pets in Havana province; Martí, Matanzas province; and also in Baracoa, Guantánamo province. This species could be invasive when limited to small areas. It is unknown now if some animals are in the wild. The animals are known to be present only as pets.

We classify the impact as No Alien populations (NA). This species reaches CL up to 82 cm. Gundlach (1880) described this taxon using mixed characters of both species *Chelonoidis denticulatus* and *C. carbonarius*.

The species has not been included in recent Cuban herpetological catalogs. Efforts to detect the animals in the wild have not been successful. As pets, they are frequently moved from one place to another.

***Centrochelys sulcata,* African Spurred Tortoise, Tortuga. Transported.**

This species is found in Necker and Guana islands, in the British Virgin Islands, and Martinique (Powell et al. 2011, 2013). Introductions in Cuba were after 1977 and the beginnings of the 1980's from Ethiopia (unpubl. data). The probable pathway was as pets for private individuals that transported them hidden in their baggage.

We believe this species arrived to Cuba through Cuban bilateral cooperation (from civil and military missions) during or after the Ethiopia-Somalia war. We have only information about four individuals. One is living in the Víbora area of Havana province. Two animals arrived in 1982; one died accidentally after arrival and the other is living in Marti town in Matanzas province (now 31-y old and weighing 30 kg). Another individual was transported in 1978 and is living in Santa Cruz del Norte, Mayabeque province.

We classify the impact as No Alien populations (NA). However, the species is a known carrier of African ticks that serve as vectors for heartwater disease (Kraus 2009). The body weight is around 100 kg, the CL is 850 mm and in its native distribution range, this species is threatened by urbanization, agriculture, and desertification (The Reptile Database. 2015. *Centrochelys sulcata*. Available from http://reptile-database.reptarium.cz/species?genus [Accsessed 17 March 2015]). In Cuba, it is restricted only to private properties and zoos.

***Malaclemys terrapin,* Diamond Backed Terrapin, Jicotea. Transported.**

This species is not currently reported in other Caribbean islands. In 1932, several individuals were introduced into Cuba and maintained in captivity in the Aquaculture Station of Ciénaga in Cerro, Havana city, before being released to several rural farmers (Gómez de la Maza 1932). The pathway was aquaculture and the individuals came from the United States (Gómez de la Maza 1932). It was part of program of importation and propagation of species from other countries for Improvement of the Cuban Fauna (Gómez de la Maza 1932). Gómez de la Maza (1932) reports that a large number of small terrapins were introduced in Cuba, but it is not clear where the animals were released. There are no animals in the wild, and no voucher specimens in Cuban collections, but one specimen is preserved in the California Academy of Sciences (CAS HERP 92987) that was collected in Soledad, Cienfuegos with unknown date.

We classify as No alien populations (NA), but more research about the species is required. The maximum CL is 12 cm for males and 19 cm for females (The Reptile Database. 2015. *Malaclemys terrapin*. Available from http://reptile-database.reptarium.cz/species?genus [Accsessed 17 March 2015]). Gómez de la Maza (1932) provided data about the reproductive biology of this species with the aim to increase the breeding in captivity for food and commercial purposes.

***Other ephemeral reptile introductions.*—**Other vagrant species of reptiles have been occasionally reported in our archipelago, with a very brief history of ephemeral presence after the importation of a few individuals. Cocteau and Bribron (1843) mentioned that the Cuban authorities previously prohibited the exhibition of rattlesnakes, as some people died as a consequence of snake bites. This is the earliest recorded measure in Cuba to control an introduced reptile. Balmaseda (1929) narrated the escape of two rattlesnakes (*Crotalus* sp.) from the Pubillones circus in Havana in 1886, one animal biting a young man who died 3 d later in the San Felipe hospital. This shows the impact of releasing a single transported animal. On November 1996, an individual of *Cnemidophorus* sp. was collected in Havana harbor in the hold of a merchant ship from Río Magdalena, Colombia. The specimen was deposited by Emilio Alfaro (National Museum of Natural History of Cuba) in the herpetological collection (MNHNCu 4408).

There is also indirect evidence of the presence in Cuba of non-native reptiles. Powell et al. (2011) referred to species of reptiles and amphibians introduced into the US from Cuba using data from the US Fish and Wildlife Service Law Enforcement Management Information System database. Possibly the animals have been introduced to the US by immigrants as pets or for religious reasons. No additional data are available but included Painted Turtles (*Chrysemis picta*) transported into the US from Cuba in 2001, Caspian Turtles (*Mauremys caspica*) in 2000, and two *Pseudemys* sp. in 1998 and 2001. Additional information on these cases is not available (Christina M. Romagosa, pers. comm.).

DISCUSSION

We document the arrival of 26 species of amphibians (five species; 20%) and reptiles (21 species; 80%) in the Cuban archipelago, with several introduction events. Only *Lithobates catesbeianus*, *Rhinella marina*, and two species of *Chelonoides* have at least three different documented introductions. Of the 26 arrivals, 11 species (two amphibians and nine reptiles) have been transported with ephemeral presence, and another 15 species have been introduced; one amphibian and 10 reptiles (73.3% of the 15 introductions) are established (invasive or not).

Additionally, nine (60% of the 15 introductions) are invasive with populations established in nature or around human settlements with different levels of impacts.

The Tens Rule by Williamson and Brown (1986) attempts to impart some predictability into the process of biological invasions, predicting that about 10% of the species introduced to an area will establish, and of those established, about 10% become invasive. As with several vertebrate cases around the world (Forsyth and Duncan 2001; Jeschke and Strayer 2005; Jeschke 2008), including those for amphibians and reptiles (Kraus 2003, 2009; Bomford et al. 2009; Ferreira et al. 2012a), our data for established and dispersed Cuban amphibians and reptiles exceeded the predicted values by the Tens Rule in both groups. Of the 86 Cuban protected areas management plans analyzed, 45 include information of at least one species of an introduced amphibian or reptile. The area with the greatest number of introduced species of these groups is the Floristic Managed Reserve San Ubaldo-Sabanalamar, in Pinar del Río province, with one introduced amphibian and four reptiles, but the report of *Hemidactylus turcicus* in this area, needs confirmation (Appendix 1). Thirty-two protected areas (37.2%) include information about introduced amphibians, whereas 24 (27.9%) include reptiles, although only one invasive amphibian (*Lithobates catesbeianus*) and six invasive reptiles are identified. Very few mitigation or management controls of invasive amphibian and reptile populations have been undertaken in Cuba. An exceptional project for the sustainable local exploitation of *Caiman crocodilus* has been developed in Isla de la Juventud to obtain economic benefits and controlling their density (Berovides et al. 2000). Additionally, some species are often misidentified and could be confused with others. For example, *H. mabouia* can be confused with *H. angulatus* (Kluge 1969), and others are cryptogenic because they are usually considered erroneously as native species in spite of their true introduced condition. Fortunately, the new Plan of the National System of Protected Areas 2014–2020 in Cuba includes a program of actions to prevent, control, and manage invasive species (Centro Nacional de Áreas Protegidas 2013). The amphibians and reptiles identified in our contribution should be made a priority in the management plans of the affected areas according to the infestation levels and impacts.

Our data on origins, probable dates, pathways, status, and potential or verified impacts of introductions provide new introduction information for Cuba. Prior to our contribution, Vales et al. (1998) only recognized three introduced species in Cuba (*Lithobates catesbeianus, Rhinella marina,*and *Caiman crocodilus*) and suggested the pathways and their known effects in nature. Kairo et al. (2003) do not report introduced herpetofauna species for Cuba, while Kraus (2009) added four species to the list (*Pseudacris crucifer, Hemidactylus mabouia, H. turcicus,* and *Sphaerodactylus argus*) and gave details of numbers, pathways, and dates of the introductions and additional data on impacts. Powell et al. (2011) made two additions (*Hemidactylus angulatus* and *H. frenatus*) and compiled nine species of introduced amphibians and reptiles in Cuba from the literature. National projects to date (2011. Cuba: Enhancing the Prevention, Control and Management of Invasive Alien Species in Vulnerable Ecosystems. Global Environment Facility Project Document. Project ID 3955. Available from http://d7.thegef.org/project_detail?projID=3955 [Accessed 17 March 2015]) do not include introduced herpetofauna in their priorities.

In spite of efforts and global initiatives, information about amphibian and reptile invasive species is not always available in books, primary literature, or international databases. In comparison with freshwater fishes, birds, and mammals, the herpetofaunal introduction data are sparse (McGeoch et al. 2012). A review of the six international invasive species databases and online compilations noted in the introduction section of this paper confirm this. For example, the IUCN Invasive Species Specialist Group (ISSG) and Global Invasive Species Database (GISD) (*op. cit*), includes 92 invasive species for Cuba, of which only one is a reptile (*Caiman crocodilus*) and two are amphibians (*Lithobates catesbeianus* and *Rhinella marina*) and *R. marina* is not present in Cuba. To ensure accurate species counts, correct knowledge about their distribution and population size, and to improve the effectiveness of eradication, prevention, and control strategies, lists of invasive species need continued revisions and updates, and the consensus of specialist judgments of each country on introduction pathways, specific locations, and impacts.

The sources of introductions diverge geographically and we are not able to find a uniform pattern. Probably most introductions have occurred from South America and Africa, but also from North America and neighboring Caribbean islands and countries (especially before the Cuban Revolution). The dates of introductions are also variable, but species have been introduced in Cuba in all historic ages: from the Colonial period (1492–1898), including the first years of colonization and the period of slavery as the two principal introduction stages, the Republic period (1901–1958), and during the Revolutionary period (1959 to date). Two important facts that we must highlight are the relationships between Cuba and the US and the level of the pet trade in Cuba. In other Caribbean islands, introduction as pets from the US, especially from Florida, have taken place (Powell et al. 2011, 2013). In contrast, in the last 54 years in Cuba, no legal introductions have had individuals from the US as a population source. Secondly, Cuba does not have a significant internal commercial pet trade with species of

amphibians and reptiles; these come only through private and illegal pathways. This situation appears to have maintained significant protection of Cuba from introduced pet species that are widespread around other parts of the Caribbean. Now that US tourism again could be a reality, increased vigilance to prevent illegal introduction should occur.

The Cuban situation is different from other Caribbean islands in terms of the species that have become established. Introduced species of *Anolis* and *Eleutherodactylus* as well as *Rhinella marina* are present in many other Caribbean islands (Powell et al 2011, 2013) but not in Cuba. Several lineages of vertebrates have undergone replicate adaptive radiations on each of the four Greater Antillean islands (Ricklefs and Bermingham 2008). Cuba has had multiple evolutionary radiations of *Anolis* lizards (Losos 2009), eleutherodactiline frogs (Hedges et al. 2008), and bufonid toads (Alonso et al. 2012). The intensity of inter-specific competition between existing native species (with extraordinary richness and morpho-ecological disparity) and introduced species could condition the success of colonization and the consequent establishment in the Cuban archipelago.

Introduced *Anolis* species have not been documented for Cuba. However, based on the rate of exotic establishments in other parts of the Caribbean, Helmus et al. (2014) estimated that Cuba could rapidly gain 1.65 anole species per year (95% CI = 1.06–2.57) should trade normalize following embargo cessation. In Caribbean islands, the invader *Anolis* are usually restricted to human environments and severely disturbed habitats (Powell and Henderson 2008) and their introductions have had little success, particularly when they have found ecologically similar species in the new area. However, few cases have been studied in detail (Losos 2009). Cuba hosts the highest diversity of native *Anolis* among Caribbean islands. Several species co-occur sympatrically within a relatively small geographic area (Rodríguez-Schettino et al. 2010; Díaz et al. 1998), and the maximum number of sympatric members of the same ecomorph class can reach four species (Garrido and Hedges 2001).

Several factors in synergy are responsible in the establishment success of herpetofauna in non-native areas (Bomford et al. 2009, Kraus 2009, Rago et al. 2012). One of the factors that positively influences establishment success of non-native reptiles is the presence of congeners in the introduced range (Ferreira et al. 2012b; Poessel et al. 2013; Mahoney et al. 2015). However, van Wilgen and Richardson (2011) concluded that reptile establishment was less likely under these conditions, and Poessel et al. (2013) recognize that at smaller geographic scales biotic resistance may be more likely. While these hypotheses are difficult to test in Cuba at present due to the peculiarities of historical conditions and available data, the ecological interactions and their consequences on the success of future introductions represent an opportunity to study the evolutionary effects of the biological invasions.

According to Simberloff and Rejmánek (2011), the greatest number of herpetofaunal introductions has occurred via the pet trade and cargo pathways. Our data confirm this tendency because most introduced species of amphibians and reptiles have reached the Cuban archipelago via illegal and underground pet trade or unintentional introductions via cargo. A few species have been introduced for food use and putative pest control, but the profitability of these projects has not been sustained in time. An example is *Rhinella marina*, with several failed introduction events in Cuba for a period of about 12 y.

Alien herpetofauna (*sensu* Kraus 2009) cause significant ecological damage to native biota through competition, predation, and hybridization (see review in Kraus 2009). The impacts are usually not clearly defined and their magnitude is not appropriately evaluated, resulting in inadequate information, because they are not based on abundance, distribution, and population dynamics data (Vilá et al. 2010; Jeschke et al. 2014). In Cuba, although inadequate information is available about the negative ecological impacts of introduced populations on indigenous biodiversity, nine amphibians and reptiles are identified as invasive species: *Lithobates catesbeianus*, *Caiman crocodilus*, three *Hemidactylus* species, *Sphaerodactylus argus*, *Gonatodes albogularis*, *Gymnophthalmus underwoodi*, and *Indotyphlops braminus*. These species can compete for resources (habitat displacement, refuges, nesting, and feeding sites), cause predation (eggs, hatchlings, and juveniles) or can produce other interferences (potential vectors for introduced parasites and diseases) with native species. They can interact with humans, creating conflicts (e.g., herpetophobia), and generate economic costs. For six of the species, it is possible to assign a category in terms of the magnitude of their impacts according to Blackburn et al. (2014). *Lithobates catesbeianus* and *Caiman crocodilus* may be the most damaging, with Major and Moderate categories, respectively. However, other species have been invasive only in specified temporal or spatial scales (e.g., *R. marina*, *A.* cf. *agama*, and *H. turcicus*). On the other hand, the ecological effects may not be clear and therefore are not always predictable or easy to evaluate (Simberloff and Rejmánek 2011; Simberloff et al. 2013).

In spite of the uncertainties in relation to impacts and arrival rates that could be increasing with time, the situation of introduced amphibians and reptiles in the Cuban archipelago does not appear to be as alarming as compared with other Caribbean islands (Powell et al. 2011). This is especially so in relation to the terrestrial area of each island. In terms of numbers of established

TABLE 1. Comparison for established amphibians (A) and reptiles (R) in Caribbean islands in relationship to the territorial areas and species richness. Species richness (total number of amphibian and reptiles species) is based on Hedges 2014 (http://www.caribherp.org [Accessed17 March 2015]) including introduced species. Our data for species richness comprises all native and established invasive and non-invasive species that were at least temporarily established, including extinct invasives and those that live only as pets of humans. Established species (ES) includes invasives and non-invasives.

Territories	Area (km^2)	Species Richness	ES	ES/km^2x100	References
Cuba	110,921	227	1A / 10 R	0.009	This review
Bahamas	13,940	68	6 A/17 R	0.164	Knapp et al. (2011), Virgil (*op. cit.*)
Cayman Islands	260	34	2 A/13 R	5.70	Echternacht et al. (2011)
Jamaica	11,500	70	4 A/3 R	0.060	Wilson (2011)
Haiti	29,472	176	2 A/2 R	0.013	Hedges (2014)
Dominican Republic	76,500	160	2 A/4 R	0.007	Powell and Incháustegui (2011)
Puerto Rico	8,900	112	6 A/4 R	0.112	Joglar et al. (2011)
Lesser Antilles	14,307	137	10 A/51 R	0.426	Powell et al. (2013)

species (ES) by square kilometer, Cuba has a relatively low index of 0.009 ES/km^2 (Table 1). According to this analysis, the most heavily introduced locations in the Caribbean are the Cayman Islands with 5.7 ES/km^2, Lesser Antilles with 0.426 ES/km^2, and Bahamas with 0.164 ES/km^2. The problem could become more complex in the future as additional research produces new evidence, identifies local impacts, and updates the number of introduced species in countries.

The fragility of small islands ecosystems (Courchamp et al. 2003; Sax and Gaines 2008) and their isolated evolution and high endemism make them an important conservation priority. However, a considerable percentage of small offshore islands and cays in the Cuban archipelago remain to be well documented for introduced and invasive species. In Cuba, the threat of invasive species has received more attention during recent years. Attention to identification, monitoring, control, and mitigation are included in the Fourth National Report to the Convention on Biological Diversity (Ministerio de Ciencia, Tecnología y Medio Ambiente 2009), with greater emphasis on invasive plants but not herpetofauna. However, in relation to protected areas, the management plans show lack of information related to introduced and invasive species, the number of specialists and researchers are inadequate, the resources for action are scarce, and information is not completely available. The situation also reflects limited perception about invasive species risks.

There is an urgent need for capacity development and for scientists to at least document accurate taxonomy of introduced and threatened species, their interaction at specific locations and the logistical and social challenges. The chronological details, the site-specific geographical information, and the new approaches toward a better understanding of impacts provided in this review can contribute to clarify some of the controversies and prioritize conservation and restoration action, as well as enrich public awareness of the dangers of invasive species. We recommend the identification of the magnitude of the problem at actionable site-specific scales, paying particular attention to the situation in protected areas and fragile ecosystems, such as small offshore islands and cays, caves, and hydrographic basins.

The cooperative Global Environment Facility project Enhancing Prevention Control and Management of Invasive Alien Species at vulnerable ecosystems in Cuba, 2011–2016 (2011. Cuba: Enhancing the Prevention, Control and Management of Invasive Alien Species in Vulnerable Ecosystems. Global Environment Facility Project Document. Project ID 3955. Available from http://d7.thegef.org/project_detail?projID=3955 [Accessed 17 March 2015]) has identified the need to fill key data gaps, manage information, manage impacts, and document best practices. These are common challenges to many countries, especially archipelagic island states. This project is a significant foundation. Conservation efforts, however, will need to be continued to ensure adequate funding to enhance scientific capacity for assessments, management, and cross-sectoral collaboration in agriculture, tourism, public health, economics, and a complementary communication and education program.

Our review is the first detailed compilation and assessment with a significant update of the list of introduced herpetofaunal species in the Cuban archipelago, especially contributing knowledge for national and international scientific and conservation databases that are deficient for these species. The paper identifies specific locations of invasive herpetofauna on the main island, offshore cays and small islands of Cuba, and protected areas. This is critical planning information needed for conservation, management, and eradication, and a timely contribution to the revision of protected area management plans now in progress. The information here alerts management authorities as to specific pathways of introduction for proactive action, especially to avoid potential for introductions through any illegal pet trade (as the cases of tortoises that have

been introduced several times in the pockets of travelers). Our contribution documents the impacts of invasive herpetofauna, data gaps, and possible directions for future research, including a comparative analysis of the situation of invasive herps in other Caribbean Islands.

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Appendix 1. Administrated Cuban Protected Areas with introduced amphibians and reptiles identified in management plans. Abbreviation: Lc, *Lithobates catesbeianus*; Hm, *Hemidactylus mabouia*; Ha, *Hemidactylus angulatus*; Ht, *Hemidactylus turcicus*; Sa, *Sphaerodactylus argus*; Ga, *Gonatodes albogularis* Cc, *Caiman crocodilus.* RN: Natural Reserve; PN: National Park; RE: Ecological Reserve; END: Outstanding Natural Element; RFM: Floristic Managed Reserve; RF: Fauna Refuge; PNP: Protected Natural Landscape; APRM: Protected Area of Managed Resources. We used Spanish acronyms for each category of protected area.

Protected Area by provinces	Amphibia	Reptilia	Managenment Plan Reference
Pinar del Río			
APRM Guanahacabibes	Lc	-	Márquez, L., G. Baena, G. Leyva, J. Camejo, O. Borrego, D. Cobián, and P. de Celis. 2012. Plan de manejo del Área Protegida de Recurso Manejados Península de Guanahacabibes 2012-2016. Manuscript CNAP, CITMA, 214 p.
PN Guanacahabibes	Lc	-	Márquez L., O. Borrego, J. Camejo, D. Cobián, J. Linares, A. Rojas, A. Sosa, and M. Puente. 2009. Plan de manejo del Parque Nacional Guanahacabibes 2009-2013. Manuscript CNAP, CITMA, 108 p.
PN Viñales	Lc	-	Novo R., M. Palacio, Y. Martínez, H. Farfán, M. López, R. Fleitas, Y. Ferrer, Y. Valdés, M. Basulto, Y. Mesa, V. Martínez, J. Echevarría, E. Miranda, M. Pérez, F. Romero, M. Becerra, and C. Díaz. 2009. Plan de manejo del Parque Nacional Viñales 2009-2013. Manuscript CNAP, CITMA, 122 p.
APRM Mil Cumbres	Lc	-	Hernández Z., A. Rodríguez, W. Cruz, K. Blanco, R. Carbonel, and Y. Forneiro. 2011. Plan de manejo del Área Protegida de Recursos Manejado Mil Cumbre 2011-2015. Manuscript CNAP, CITMA, 140 p.
RFM San Ubaldo-Sabanalamar	Lc	Ht, Hm, Ga, Sa	Ramírez F., G. Izquierdo, O. Gonzáles, Y. Sosa, E. Vega, M. Prieto, G. García, L. Pérez, I. Delgado, and M. Ramos. 2010. Plan de manejo de la Reserva Florística Manejada San Ubaldo-Sabanalamar 2010-2014. Manuscript CNAP, CITMA, 90 p.
Artemisa			
APRM Sierra del Rosario	Lc	-	Anonymous. 2011. Plan de manejo de la Reserva de la Biósfera Sierra del Rosario 2011-2015. Manuscript CNAP, CITMA, 106 p.
Havana			
RE La Coca	Lc	-	Montero A., and M. Fajardo. 2012. Plan de manejo de la Reserva Ecológica La Coca 2012-2016. Manuscript CNAP, CITMA, 215 p.
PNP Isla Josefina	Lc	Ha, Ga	Almonte D., A. Miranda, Y. Pérez, I. Seigle, M. Bianchi, L. Domínguez, L. Govantes, E. Rodríguez, and J. Medina. 2010. Plan de manejo del Paisaje Natural Protegido Isla Josefina 2010-2015. Manuscript CNAP, CITMA, 111 p.
Mayabeque			
PNP Escaleras de Jaruco	Lc	-	Villasuso I., A. Florido, R. Román, R. Rodríguez, A. Vidal, H. Fuentes, F. González, J. Travieso, A. García, and D. Perdomo. 2011. Plan de manejo del Paisaje Natural Protegido Escaleras de Jaruco 2011-2015.Manuscript CNAP, CITMA, 149 p.
Isla of Youth			
RE Punta del Este	-	Ha	Anonymous. 2006. Plan de manejo de la reserva Ecológica de Punta del Este 2006-2010. Manuscript CNAP, CITMA, 66 p.
RE Los Indios	-	Cc	Borrego R., P. Rodríguez, I. Otero, F. Kiala, J. Osorio, M. Delgado, S. Álvarez, M. Mayet, D. Ried, A. Pérez, and J. Silva. 2011. Plan de manejo de la Reserva Ecológica Los Indios 2011-2015. Manuscript CNAP, CITMA, 39 p.
Matanzas			
PN Ciénaga de Zapata	Lc	Ha, Sa	Anonymous. 2010. Plan de manejo del Parque Nacional Ciénaga de Zapata 2010-2014. Manuscript CNAP, CITMA, 208 p.
APRM Ciénaga de Zapata	Lc	-	Jiménez J., J. González, T. Piñeiro, S. Álvarez, Y. González, R. Santana, L. Caballero, Y. Reyes, and M. Blanco. 2011. Plan de manejo del Área Protegida de Recursos Manejados Península de Zapata 2011-2014, Plan Operativo. Manuscript CNAP, CITMA, 171 p.
PNP Varahicacos	-	Ha, Ga	Fajardo D., J. García, R. Rodríguez, E. Reyes, R. Trujillo, R. Navia, B. Fumero, and H. Fernández. 2012. Plan de manejo del Paisaje Natural Protegido Varahicacos 2012-2016, Manuscript CNAP, CITMA, 137 p.

END Caverna de Santa Catalina	-	Ha	González E., I. Vázquez, I. Z. de la Torre, Z. S. Monzón, E. Vento. 2010. Plan de manejo del Elemento Natural Destacado Cavernas Santa Catalina 2010-2014. Manuscript CNAP, CITMA, 49 p.
RF Laguna de Maya	-	Ga, Ha	Soto L., N. Falcón, T. Hernández, R. Santana, and A. Mena. 2012. Plan de manejo del Refugio de Fauna Laguna de Maya 2012-2016. Manuscript CNAP, CITMA, 111 p.
PNP Río Canímar	-	Ha	Villasuso I., L. Soto, D. Sánchez, R. Santana, A. Mena, I. Villalonga, R. Gacet, and J. Cárdenas. 2012. Plan de manejo del Paisaje Natural Protegido del Valle Río Canímar 2012-2016. Manuscript CNAP, CITMA, 138 p.
RF Bermejas	Lc	Sa	Medina F., A. Martínez, M. Nodarse, O. Ramírez, and S. Alvarez. 2013. Plan de manejo de la Reserva de Fauna Las Bermejas 2013-2017. Manuscript CNAP, CITMA, 116 p.
END Sistema Espeleolacustre de Zapata	Lc	Sa	Abreu E., S. Álvarez, T. Piñeiro, and R. Oviedo. 2013. Plan de manejo del Elemento Natural Destacado Sistema Espeleolacustre de Zapata 2013-2017. Manuscript CNAP, CITMA, 213 p.
Villa Clara			
RE Mogotes de Jumagua	Lc	-	Triana M., D. Ballate, I. Díaz, J. Santos, J. Matos, O. Bermúdez, B. Alonso, J. Ramón, A. Vásquez, M. García, D. Alonso, M. Domínguez, and M. Fernández. 2011. Plan de manejo Reserva Ecológica Mogotes de Jumagua 2011-2015. Manuscript CNAP, CITMA, 79 p.
PNP Hanabanilla	Lc	-	Anonymous. 2012. Plan de manejo del Paisaje Natural Protegido Hanabanilla 2012-2016. Manuscript CNAP, CITMA, 125 p.
RFM Monte Ramonal	Lc	Ha	Anonymous. 2009. Plan de manejo de la Reserva Florística Manejada Monte Ramonal 2009-2013. Manuscript CNAP, CITMA, 65 p.
RF Cayo de Santa María		Ha	Anonymous. 2010. Plan de Manejo de Refugio de Fauna Cayo Santa María. Version preliminar Delegación Provincial de Gaviota, MINTUR, Villa Clara. Manuscript CNAP, CITMA, 93 p.
Sancti Spiritus			
PNP Topes de Collantes	Lc	-	Ruiz I., B. Naranjo, N. Albelo, A. Rodríguez, L. Cruz, O. Duardo, D. Sarduy, I. Arboáez, E. Pulido, V, Santisteban, and A. Reyes. 2011. Plan de manejo del Paisaje Natural Protegido Topes de Collantes 2011-2015. Manuscript CNAP, CITMA, 96 p.
RE Lomas de Banao	Lc	Ha, Ga	Martín H., R. Arbella, Y. Urquiza, O. Valle, O. Sotolongo, R. Arriola, Y. Gallo, Y. Zamora, R. González, M. Cruz, O. Meneses, J. Ramón, A. Valle, O. Cepeda, G. García, V. Santiesteban, and E. Pulido. 2011. Plan de manejo Reserva Ecológica Lomas de Banao 2011-2015. Manuscript CNAP, CITMA. 210 p.
PN Caguanes	Lc	Ha	Sánchez E., A. Martínez, I. Hernández, C. Fernández, N. Pujol, J. Remigio, M. Rodríguez, E. Ramos, F. Perdomo, J. Chirino, A. Betancour, and J. Oñate. 2009. Plan de manejo del Parque Nacional Caguanes 2009-2013. Manuscript CNAP, CITMA, 341 p.
APRM Jobo Rosado	Lc	-	Falcón A., F. Morera, O. Cepeda, L. Pérez, Y. González, M. Hernández, Y. Prieto, G. García, I. Borroto, V. Santiesteban, D. Sánchez, T. Castillo, J. Hernández, and Y. Morales. 2010. Plan de manejo del Área Protegida de Recursos Manejados Jobo Rosado 2010-2014. Manuscript CNAP, CITMA, 93 p.
RFM Lebrije	Lc	Ha, Ga	Santiesteban V., O. Cepeda, G. García, I. Conte, A. Paz, J. Betancourt, M. Carriles, Y. Jiménez, and M. Iglesia. 2010. Plan de manejo de la Reserva Florística Manejada Lebrije 2010-2014. Manuscript CNAP, CITMA, 85 p.
RFM Lomas de Fomentos	Lc	-	González Y., Y. Martínez, N. Borroto, R. Marichal, T. Díaz, O. Cornelio, M. Pino, V. Santiesteban, O. Cepeda, and A. Falcón. 2010. Plan de manejo de la Reserva Florística Manejada Lomas de Fomento 2010-2014. Manuscript CNAP, CITMA, 53 p.
Ciego de Avila			
RF Loma de Cunagua	Lc	-	Anonymous. 2009. Plan de manejo de Refugio de Fauna Lomas de Cunagua 2009-2013. Manuscript CNAP, CITMA, 103 p.

RE EL Venero	Lc	-	Anonymous. 2012. Plan de manejo del Refugio de Fauna El Venero 2012-2016. Manuscript CNAP, CITMA, 73 p.
Camaguey			
APRM Humedal de Cayo Romano	Lc[1]	Ha	Lake J., T. Pérez, Y. Forneiro, M. Pérez, J. Jomarron, M. Borges, G. Abad, Y. Martin, L. Díaz, R. del Risco, D. Sánchez, C. Franquel, and L. Pérez. 2010. Plan de manejo del Área Protegida de Recursos Manejados Humedales de Cayo Romano y Norte de Camagüey 2010-2014. Manuscript CNAP, CITMA, 92 p. [1]Luis M Díaz (pers comm).
RF Río Máximo	Lc	-	Anonymous. 2010. Plan de manejo del Refugio de Fauna Río Máximo 2010-2014. Manuscript CNAP, CITMA, 110 p.
PN Jardines de la Reina	-	Sa	Anonymous. 2007. Plan de manejo del Parque Nacional Jardines de la Reina 2007-2011. Manuscript CNAP, CITMA, 98 p.
APRM Sierra del Chorrillo	Lc	-	Jomarron J., M. Borges, J. Lake, G. Abad, Y. Forneiro, T. Pérez, L. Díaz, D. Jiménez, A. Puig, D. Sánchez, R. del Risco, and Y. Martín. 2010. Plan de manejo del Área Protegida de Recursos Manejados Sierra del Chorrillo 2010-2014. Manuscript CNAP, CITMA, 138 p.
RE Limones Tubaquey	Lc	-	León M., M. Borges, O. Brito, D. Godínez, E. Figueredo, Y. Martín, I. Hernández, D. Peláez, J. Primelles, K. Maure, and J. Pestana. 2011. Plan de manejo de la Reserva Ecológica Limones-Tubaquey 2011-2015. Manuscript CNAP, CITMA, 137 p.
Holguín			
PN Pico Cristal	-	Ha	Anonymous. 2010. Plan de manejo del Parque Nacional Pico Cristal 2010-2014. Manuscript CNAP, CITMA, 168 p.
PN La Mensura-Pilotos	Lc	Ha, Ga	Anonymous. 2010. Plan de manejo del Parque Nacional La Mesura-Piloto 2010-2014. Manuscript CNAP, CITMA, 119 p.
Granma			
PN Desembarco del Granma	-	Ga	Palacios L., R. Escalona, Y. Cala, S. Calaña, C. Ocano, L. Alayón, J. Pérez, G. Cisneros, O. Sariego, and A. Ramón. 2012. Plan de manejo del Parque Nacional Desembarco del Granma 2012-2016. Manuscript CNAP, CITMA, 195 p.
PN Pico Turquino	Lc	-	Lastres I., P. Hernández, J. Gómez, J. Pérez, and P. López. 2012. Plan de manejo del Parque Nacional Turquino 2012-2016. Manuscript CNAP, CITMA, 146 p.
RF Delta del Cauto	Lc	Ha, Sa, Ga	Labrada P., I. Verdecia, J. Pérez, L. Figueredo, A. Infante, M. F. Granado, and A. Reyes. 2012. Plan de manejo del Refugio de Fauna Delta del Cauto 2012-2016. Manuscript CNAP, CITMA, 95 p.
RF Humedales de Río Gua y cayos de Manzanillo	-	Ha, Ga	Cisneros G., L. Fuentes, M. Pérez, M. López, L. Nuvea, Y. Alarcón, L. Verdecía, H. Ramírez, J. Milanés, V. Tornes, A. Martínez, R. Gil, D. Ramos, and R. Machado. 2011. Plan de manejo del Refugio de Fauna Humedales del Río Gúa y Cayos de Manzanillo 2011, Plan Operativo, Manuscript CNAP, CITMA, 74 p.
Santiago de Cuba			
RE Siboney-Jutisí	-	Ha	Salmerón A., A. González, L. Álvarez, A. Reyes, and G. Acosta. 2009. Plan de manejo de la Reserva Ecológica Siboney-Jutisí 2009-2013. Manuscript CNAP, CITMA, 41 p.
Guantánamo			
PN Alejandro de Humboldt	Lc	-	Villaverde R., G. Begué, C. Giraudy, H. Pérez, R. Ubals, R. Acebal, Y. Joubert, N. Hernández, P. Correa, A. Medina, G. Rodríguez, R. Guarat, and G. Llorente. 2009. Plan de manejo del Parque Nacional Alejandro de Humboldt 2009-2013. Manuscript CNAP, CITMA, 162 p.
RE Hatibonico	-	Ha	Villaverde R., G. Begué, C. Giraudy, H. Pérez, R. Ubals, R. Acebal, Y. Joubert, R. Acebal, and R. Guarat. 2009. Plan de manejo de la Reserva Ecológica Hatibonico 2009-2013. Manuscript CNAP, CITMA, 127.
Total Protected Areas	32	25	

Appendix 2. The number of introduced and invasive amphibians and reptiles in Cuba with records in US and Cuban collections (number of specimens in parentheses). We found 11 species in Cuba that are not in any collection: *Chelonoidis denticulatus*, *Chelonoidis carbonarius*, *Centrochelys sulcate*, *Crotalus* sp.1 and sp. 2, *Chrysemis picta*, *Mauremys caspica*, *Pseudemys* sp., *Pseudacris crucifer*, *Hoplobatrachus tigerinus*, *Osteocephalus* sp. Acronyms for US collections: AMNH, American Museum of Natural History, New York; ANSP, Academy of Natural Sciences of Philadelphia; CAS, California Academy of Sciences; CM, Carnegie Museum of Natural History; FLMNH, Florida Museum of Natural History; KU, Kansas Biodiversity Institute; LACM, Natural History Museum of Los Angeles County; MCZ, Museum of Comparative Zoology, Harvard; MPM, Milwaukee Public Museum; SDNHM, San Diego Natural History Museum; TCWC, Texas A&M University Biodiversity Research and Teaching Collections; UMMZ, University of Michigan Museum of Zoology; USNM, National Museum of Natural History, Smithsonian Institution. Acronyms for Cuban collections: CZACC, Institute of Ecology and Systematic; BSC.H, Eastern Center for Ecosystems and Biodiversity (BIOECO); MNHNCu, National Museum of Natural History of Cuba.

Taxa	US collections	Cuba collections
Caiman crocodilus	CM (1), KU (1) [Doubtful Records].	-
Hemidactylus mabouia	USNM (37), KU (20), MCZ (9), SDNHM (8), MPM (3).	CZACC (1), MNHNCu (3)
Hemidactylus angulatus	AMNH (38), LACM (11), USNM (6), UMMZ (1).	CZACC (144)
Hemidactylus frenatus	-	MNHNCu (90)
Gonatodes albogularis fuscus	AMNH (92), USNM (48), MCZ (9), LACM (9), KU (8), ANSP (8), FLMNH (7), TCWC (2), UMMZ (1).	CZACC (120)
Sphaerodactylus argus	CAS (87), MCZ (29), AMNH (10), USNM (7), FLMNH (2), UMMZ (1).	CZACC (16)
Gymnophthalmus underwoodi	-	BSC.H (4)
Indotyphlops braminus	-	MNHNCu (4)
Hemidactylus turcicus	USNM (4), AMNH (4), MCZ (3), UMMZ (1).	CZAAC (2)
Malaclemys terrapin	CAS (1).	-
Cnemidophorus sp.	-	MNHNCu (1)
Lithobates catesbeianus	USNM (22), FLMNH (3), AMNH (1).	CZACC (33)
Rhinella marina	USNM (6), AMNH (4) [Doubtful Records].	